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DEVELOPMENT OF LEG WHEEL HYBRID HEXAPOD BOT

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ABSTRACT

The conventional mobile robotic platforms which either uses wheels or legs are quite familiar and each one of them has its own advantages and disadvantages. The wheeled robot is suitable for only plain and smooth terrain, whereas the legged robot can travel in any kind of terrain but is comparatively slower than the wheeled robot. So, a hybrid of both wheeled and legged platform would be quite suitable for any kind of terrain. The primary focus of this project is to design and develop a leg-wheel hybrid robotic platform with a concurrent engineering and mechatronics approach to produce results with optimised design metrics at each and every stage of its development. This paper details the Finite Element Analysis (FEA) of the C – Legs which are used in the robot.

***Keywords**: All terrain, c – leg, hexapod, hybrid, leg, mobile robot, wheeled robot.*

INTRODUCTION

Mobile robots are becoming quite essential now a days, as a deliberate need of robots has occurred in the field of exploration and surveillance in unknown terrain and environment. So, various advancement in locomotive mechanisms are continuously being researched and developed all over the world which would suit all the needs and make the robot quite adaptable to the unknown environment. One such advanced locomotive mechanism called the leg-wheel hybrid mechanism where the bot uses a hybrid of both leg like rotating C-Curves and wheels for locomotion. Furthermore, the suitable actuators that are used in the bot along with the programming implementation procedure has also been described in this paper.

This entire paper is structured as follows, section 2 covers the basic design specification of the bot, section, section 3 describes about the C-Leg bending calculations, material selection and analysis and section 4 is the conclusion of this research work and the future work to be done.

BASIC DESIGN OF THE BOT

Even though the leg-wheel hybrid mechanism in which the C-Leg used by the bot can be transformed into a wheel like structure is quite familiar and common, it has got lot of disadvantages like the transformation time in between the C-Leg and the wheel is quite high and not always reliable. The complexity in constructing such a mechanism is also very high and robustness of the system also reduces. So, considering all these facts, a simple and reliable design is developed for this bot as shown in Fig. 1 and Fig. 2. In this design the bottom panel of the bot holds the wheels, which will come in contact to the ground when all the legs are lifted up at once.

Fig. 1. Basic design outlook of the bot in standing position using its C-Legs.

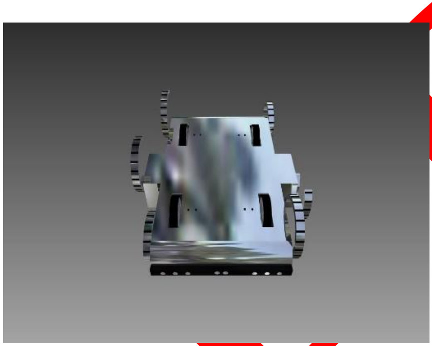

Fig. 2. Bottom panel of the bot with its four wheels attached

The six C-Legs which are used in the bot gives it a good grip and stable walking position without much disturbances for the components inside the bot. The entire body of the body is made up of aluminium and the C-Legs are constructed using Manganese Steel. The detailed analysis of the C-Leg is described in the next section. The bot moves using its C-Legs in uneven and difficult terrains in which the speed of movement will not be a main concern. In all other cases the bot would use its wheels for its locomotion. Compactness and robustness were the two main parameters which were considered while designing this bot.

ANALYSIS OF C-LEG

This section is primarily concentrated with the material selection and analysis of the C-Leg used in the bot. The details regarding the material selection for the C – Leg is as shown in Table 1.

Table 1. Material Specification of the C – Leg

Name	Aluminum 6061	
General	Mass Density	2.7 g/cm^3
	Yield Strength	275 MPa
	Ultimate Tensile Strength	310 MPa
Stress	Young's Modulus	68.9 GPa

	Poisson's Ratio	0.33 ul
	Shear Modulus	25.9023 GPa
Part Name(s)	LEG	

After the material selection procedure, the mesh settings is done as shown in the Table 2.

Table 2. Mesh settings for FEA

Avg. Element Size (fraction of model diameter)	0.005
Min. Element Size (fraction of avg. size)	0.01
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

For instance, only one C – Leg out of six is taken into consideration as shown in the Fig. 4, and analysed.

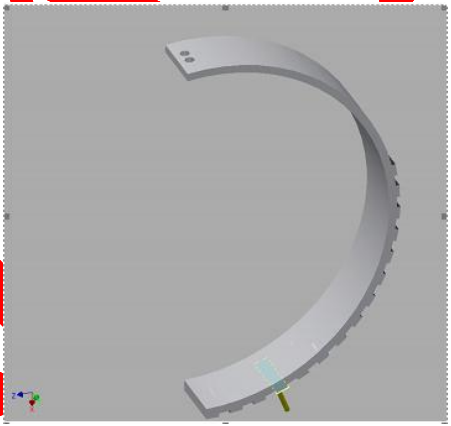

Fig. 4. Unit C – Leg of Hexapod

In order to make the calculations simpler, a predefined constrain is fixed and the primary for specification is made according to the Table 3.

Table 3. Force specifications

Load Type	Force
Magnitude	10.000 N

Vector X	-9.309 N
Vector Y	0.000 N
Vector Z	3.653 N

So, after the material selection, mesh settings, force and constrain definition, the FEA on C – Leg is done and the results are obtained as follows. The Table 4, represents the reaction for and moment on the defined constraints and the Table 5, depicts the entire result of the FEA process done.

Table 4. Reaction force and Reaction moment on constraints

Constraint Name	**Reaction Force**		**Reaction Moment**	
	Magnitude	**Component (X,Y,Z)**	**Magnitude**	**Component (X,Y,Z)**
Fixed Constraint:1	10 N	9.30874 N	0.163141 N m	0 N m
		0 N		0.163141 N m
		-3.65341 N		0 N m

Table 5. FEA complete result

Name	**Minimum**	**Maximum**
Volume	9699.56 mm^3	
Mass	0.0261888 kg	
Von Mises Stress	0.00342306 MPa	50.9313 MPa
1st Principal Stress	-11.1816 MPa	62.5941 MPa
3rd Principal Stress	-37.8314 MPa	18.7251 MPa
Displacement	0 mm	3.21907 mm
Safety Factor	5.39943 ul	15 ul
Stress XX	-31.2069 MPa	58.777 MPa
Stress XY	-6.78295 MPa	6.45903 MPa
Stress XZ	-21.3637 MPa	17.6197 MPa

Stress YY	-16.2938 MPa	21.8471 MPa
Stress YZ	-7.15734 MPa	6.77936 MPa
Stress ZZ	-32.653 MPa	39.0959 MPa
X Displacement	-1.53503 mm	0.529129 mm
Y Displacement	-0.00118438 mm	0.00118522 mm
Z Displacement	-0.00135727 mm	2.8295 mm
Equivalent Strain	0.0000000831891 ul	0.000678095 ul
1st Principal Strain	-0.000000049409 ul	0.000775757 ul
3rd Principal Strain	-0.000460967 ul	0.0000000922365 ul
Strain XX	-0.000430334 ul	0.00076541 ul
Strain XY	-0.000130934 ul	0.000124681 ul
Strain XZ	-0.000412391 ul	0.000340118 ul
Strain YY	-0.00018817 ul	0.000139202 ul
Strain YZ	-0.000138161 ul	0.000130864 ul
Strain ZZ	-0.000318095 ul	0.00037109 ul

While in motion when these C-Legs are subjected to load, even though there is deflection behaviour seen in these compliant legs, its magnitude and orientation is quite difficult to be calculated as there are quite a lot parameters to be considered which is mostly dependent upon the environment and the grips used for the C-Legs.

There are actually two models to analyse the C-Leg bending mechanisms, Pseudo Rigid Body (PRB) Model and Topology Optimisation.

In this case PRB model is used for bending analysis because the Topology Optimisation model requires specific boundary conditions for a given design space. Also, in PRB model, the leg stiffness can be easily calculated for different configurations and dimensions easily.

So in this PRB model, the point of deflection is first found out and a pivot point is set, from where the actual bending starts as shown in the Fig. 5.

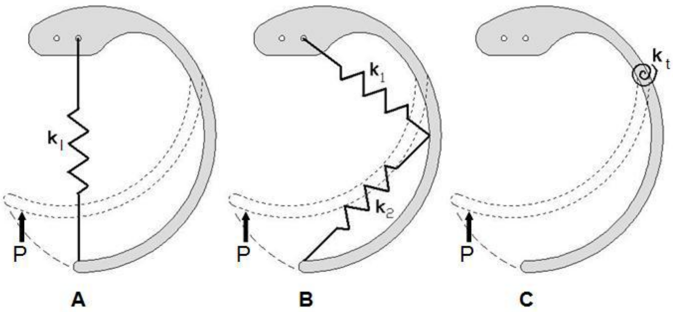

Fig. 4. Determining the location of pivot point for bending in the C-Leg based on the spring stiffness k_1 and k_2 when being subjected to a load P.

The actual loading point does not occur in the tip of the complaint leg, because once the load is given the leg bends with an angle, which is the PRB angle (this angle is based on the overall load of the bot or the load acting on individual legs) and rests at a point called the loading point. The pseudo rigid body link is the measure from the pivot point and the loading point. The PRB angle is found with respect to the PRB link. The flexible region starts from the pivot to the loading point where the stiffness factor is considered to be less.

CONCLUSION AND FUTURE WORK

In this paper the basic outlook of the Leg Wheel Hybrid Hexapod is detailed and the main focus of this paper is to analyse the C – Leg used in the hexapod. FEA is carried out on the hexapod and the results are presented. The future scope of this project would be is to concentrate on the electronics and programming layout of the hexapod and to implement advanced machine learning algorithm in it.

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